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퍼텐션 필드법을 이용한 모바일 로봇의 경로디자인

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Trajectory Design for Mobile Robot Using Potential Field Method

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Abstract

This study presents a potential field method for path planning to goal with a mobile robot in unknown environment. The proposed algorithm allows mobile robot to navigate through static obstacles, and find the path in order to reach the target without collision. This algorithm provides the robot with the possibility to move from the initial position to the final position (target). Stage and Player simulator is used to perform the robot motion and implement the potential field algorithm in C/C++ for performance evaluation. Two-dimensional terrain model is used to simulate the ability of robot in motion planning without any collision.

1. Introduction

Autonomous robots which work without human operators are required in robotic fields. In order to achieve tasks, autonomous robots have to be intelligent and should decide their own action. When the autonomous robot decides its action, it is necessary to plan optimally depending on their tasks. Moreover, it is essential to sketch the collision free path minimizing the cost in time, energy and distance when an autonomous robot navigates from initiate point to a target in its given environment. Therefore, the major work of path planning for autonomous mobile robot is to search a collision free path.

Given the prior knowledge of the environment and the goal position, mobile robot navigation relies on the robot's ability to safely move towards the goal using its knowledge and the sensory information of the surrounding environment. Accordingly, the proposed algorithm is used as the potential field method. The potential field method for autonomous robot navigation consists essentially in the assignment of an attractive potential to the goal point and a repulsive potential to each of the obstacles in the environment.

2. Related Work

O.Khatib [1] presented a unique real-time obstacle avoidance approach for manipulators and mobile robots based on the artificial potential field concept. This method has been implemented in the COSMOS system for a PUMA 560 robot. Real-time collision avoidance demonstrations on moving obstacles have been performed by using visual sensing.

In [2], the authors presented a systematic overview and a critical discussion of the inherent problem of potential field methods (PFMs). The authors abandoned potential field methods and developed a new method for fast obstacle avoidance.

3. Potential Field Method

Path planning using potential fields is based on a simple and powerful principle, first proposed by O. Khatib in [1]. The robot is considered as a particle that moves immersed in a potential field generated by the goal and by the obstacles presence in the environment. The goal generates an attractive potential while each obstacle generates a repulsive potential. A potential field can be viewed as an energy field and so its gradient, at each point, is a force. The robot immersed in the potential field is subject to the action of a force that drives it to the goal (it is the action of the attractive force that results from the gradient of the attractive potential generated by the goal) while keeping it away from the obstacles (it is the action of a repulsive force that is the gradient of the repulsive potential generated by the obstacles).

3.1. The Force Field Function

In general, the robot is represented as a particle under the influence of a scalar potential field U, defined as:

$$U = U_{att} + U_{rep} \qquad \text{[Eq.1]}$$

where U_{att} and U_{rep} are the attractive and repulsive potentials, respectively. The attraction influence tends to pull the robot towards the target position, while repulsion tends to push the robot away from the obstacles. The vector field of artificial forces $F(q)$ is given by the gradient of U:

$$U(q) = -U_{att} - U_{rep} \qquad \text{[Eq.2]}$$

where ∇U is the gradient vector of U at robot position $q(x,y)$ in a two dimensional map. In this manner, F is defined as the sum of two vectors $F_{att}(q) = -\nabla U_{att}$ and $F_{rep}(q) = \nabla U_{rep}$.

$$F(q) = F_{att}(q) + F_{rep}(q) \qquad \text{[Eq.3]}$$

3.2. Attractive force

A hybrid method with parabolic and conic wells, the formulation of attractive function and its gradient are:

$$\vec{F}_{att}(att) = \begin{cases} -\xi(q - q_{goal}) & if\left\|q - q_{goal}\right\| \le d \\ -\xi \dfrac{d(q - q_{goal})}{\left\|q - q_{goal}\right\|} & if\left\|q - q_{goal}\right\| > d \end{cases} \qquad \text{[Eq.4]}$$

where q is the robot position, q_0 is the position of the attraction point, and ξ is a control variable for the gradient magnitude, and d presents the limit for using quadratic formula.

3.3. Repulsive force

The negative of the gradient of the repulsive potential of obstacle i is given by,

$$\vec{F}_{rep}(q) = \begin{cases} \eta\left(\dfrac{1}{\rho_i(q)} - \dfrac{1}{\rho_o}\right)\dfrac{1}{\rho_i^2(q)}\vec{\nabla}\rho_i(q) & if \rho_i(q) \le \rho_o \\ 0 & if \rho_i(q) > \rho_o \end{cases}, \quad \text{[Eq.5]}$$

where $\rho_i(q)$ is the minimal distance from q to the obstacle i, η is a scaling constant, and ρ_0 is a positive constant – distance of influence.

4. Performance Evaluation

We evaluate the performance of the algorithm by extensive simulations. The performance evaluation is simulated by changing the parameters such as velocity and the influent distance of force to test the influence on the robot trajectory and the ability of collision avoidance. We design two-dimensional terrains with seven diamonds, one regular pentagon and one right triangle arranged to create many roads with the size of bit map: 16mx16m. The scale between real map and simulation screen is 1 unit: 1m. All simulations are based on the Pioneer 2 mobile. The Pioneer 2/PeopleBot microcontroller comes with 32K flash-programmable, read-only memory (FLASH-ROM). It contains a number of sensors including a laser navigation finder, two arrays of sonar sensors, bumper sensors, cameras, and a GPS system.

4.1. Velocity profile with different value

The simulated paths for this experiment are shown in Fig. 1 with the velocity values of 0.3m/s, 0.5m/s, and influence distance of force ρ_0 = 1.5m. The start position is (-4, -7) and goal position is (-3, 7). The velocity values are changed to estimate the real-time collision avoidance capability and the efficiency of potential algorithm. Moreover, the simulation results are used to indicate the influence of velocity parameter on the path planning process.

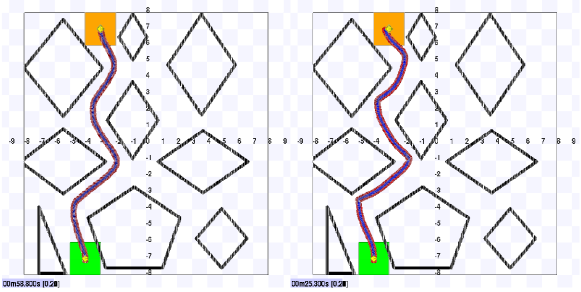

Fig 1. Robot moves to goal with a velocity of 0.3m/s, 1m/s and ρ_0 =1.5m, respectively.

4.2. Adaptive capability

The influential distance of force is set with value of 1.5m and v = 0.5m/s (velocity profile). The same terrain model is chosen for simulation experiment but the value of start and goal positions are changed to evaluate the adaptive capability of potential field method: first experiment with start position (2.5, -7), goal position (-3, 7), and the second with start position (7, -5), goal position (-3, 7) in Fig. 2, respectively.

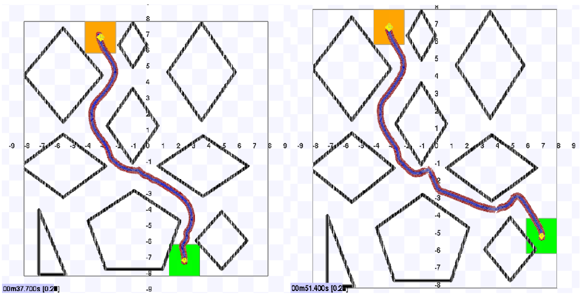

Fig 2. Robot moves to goal with v =0.5m/s and ρ_0 =1.5m.

5. Conclusion

Robot moves smoothly with low velocity rather than high velocity. It is observable that planed trajectory with velocity of 0.3m/s create smoother curve than the velocity of 1m/s.

The start and goal positions are varied to demonstrate the path planning or adaptive capability in different terrains. The mobile robot could also move to goal and guarantee collision free robot trajectory in diverse terrains. It is possible to deal with dynamic environment, regularly replanning the robot's path by detecting the change of sensory information from surrounding environment simultaneously.

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Reference

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